Coastal Artificial Reef Planning Guide

Prepared By

The Joint Artificial Reef Technical Committee
of the Atlantic and Gulf States Marine
Fisheries Commissions

December 1998

This project was conducted in cooperation with the U.S. Fish and Wildlife Service, and funded by Federal Aid in Sport Fish Restoration Administrative Funds, FWS Grant Agreement Nos. GS-96 and AP-98-501.

Support was also provided by the National Marine Fisheries Service.

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ACKNOWLEDGMENTS

Gratitude is given to the National Marine Fisheries Service for working cooperatively with the three interstate marine fisheries commissions and their member states to begin an effort to revise the National Artificial Reef Plan. Claire Miller worked diligently to prepare documents that facilitated full review of the 1985 National Artificial Reef Plan, along with many hours of coordination and communication that led to completion of the document, and for her efforts she is acknowledged and thanked. Throughout the revision process Nancy Marcellus provided constant and professional support culminating in the final draft of this document. Gratitude is offered to her for her contribution to the process and its results. While this was a drafting effort to which many people contributed, Richard Christian is thanked for his primary drafting role, and for incorporating each individual writer's words into a smoothly flowing document. Finally, thanks are given to the many contributors to the document, represented by many hours of research and writing.

PREFACE

The original National Artificial Reef Plan (Plan) was published in 1985. On Page 1 of the document in the Introduction, the last sentence of the first paragraph states "The Plan is intended as a dynamic, working document that will change as new information becomes available." By letter to the National Marine Fisheries Service (NMFS) in the Spring of 1996, the three interstate marine fisheries commissions requested that the NMFS authorize them to engage in revising the Plan. In December 1996, the NMFS responded, providing the commissions the authority to draft recommendations for full plan revision.

The rationale for the interstate marine fisheries commissions to assume the lead role in revising the National Plan is that over the last 10 to 15 years, state artificial reef management programs, which typically interact through the Gulf and Atlantic States Marine Fisheries Commissions, have been the most visible in artificial reef development, and, therefore, their programs are more integrally tied to the guidance provided in the Plan. It is in the spirit of regional and national cooperation and coordination of activities that the state artificial reef programs made the decision to apply their hard-won knowledge and experience to revising the Plan.

Over the subsequent two years, the state programs, through interstate commission coordination, completed full revision of the Plan, which is contained in this document, and transmitted it to the NMFS for consideration to replace the 1985 Plan. Prior to that occurring, the then draft plan was adopted by all three interstate marine fisheries commissions as their recommendation for national policy on artificial reef development and management. In that regard, this document represents the general policy of the three commissions and exists separately from the Plan. It is understood that through the federal review process, consisting of extensive federal agency and public input, there may be some changes made to the document prior to final consideration for replacing the current Plan. Those changes do not affect the recommendations contained within this document. The three interstate marine fisheries commissions and their member states will continue to participate in revision of the Plan throughout the federal review process and are optimistic that subsequent to that process we will establish new national policy for artificial reef development and management for which we can all be proud.

EXECUTIVE SUMMARY

The National Artificial Reef Plan (Plan) was developed by the Secretary of Commerce under direction of the National Fishing Enhancement Act of 1984 (Act). The Plan was designed to be a dynamic working document that would be updated as new information became available. Prior to 1984, many coastal states had well developed programs directed at enhancing fisheries and fish habitat with man-made reef structures. Following approval of the Plan in 1985, these states were joined with others in assuming the lead role in implementing its recommendations. Many have pursued aggressive construction programs under guidance of the Plan and specific regulation in the Act. In addition, some state agencies have been less active in constructing reefs, but rather have made financial and technical resources available to local governments, private interests, and universities to encourage responsible reef development and research. The body of current knowledge and expertise in manmade reef development and technology has been produced either directly or indirectly through all these state efforts. This document represents the collective knowledge and policy direction of the state programs, through the interstate marine fisheries commissions, and is intended to be complementary to the Plan and any subsequent revisions thereto.

Approximately half of the 29 coastal state natural resources agencies in the United States have approved plans for construction of manmade fish habitat based on the guidance of the Plan. In developing these plans and implementing individual state programs, these agencies have taken advantage of the coordination function for their respective interstate marine fisheries commissions to share experiences and technologies. The interstate commissions have served to assist coordination of information exchange, and development of coastal and national policies for responsible stewardship of the fisheries affected by manmade reef development activities. In 1995, the Artificial Reef Technical Committees of the Atlantic and Gulf States Marine Fisheries Commissions voted to work jointly to prepare recommendations to the Secretary to revise the Plan incorporating new information and technological advances acquired through their collective experiences. The Pacific States Marine Fisheries Commission has joined in support of these recommendations, making this a joint policy among the three interstate marine fisheries commissions and their member states along the Pacific and Atlantic Oceans and the Gulf of Mexico.

This document follows the format of the 1985 Plan incorporating changes to original text in key areas. The Atlantic and Gulf States Marine Fisheries Commissions coordinated development of these changes over a three-year period through open debate in public fora among state manmade reef program developers, involved federal agencies and many affected constituencies. As extensive as such debates may have been, all participating entities realize that any changes to the Plan which may result from this work must pursue another phase of reviews under the purview of the National Marine Fisheries Service as the responsible agent of the Secretary of Commerce. This phase may change recommendations offered by the states to the Secretary, and if implemented, will supercede current National policy. Therefore this is a stand alone document and represents the broad policies and recommendations of the interstate marine fisheries commissions regarding marine manmade reef development in state and federal waters.

The Act designates the Secretaries of Commerce and the Army with lead responsibilities to encourage, regulate and monitor development of manmade reefs in the navigable waters of the United States. The Secretary of Commerce is responsible for the Plan which provides guidance on reef development. The Secretary of the Army has lead responsibility to regulate and monitor manmade reef projects through pertinent permit programs of the U.S. Army Corps of Engineers (Corps). The coastal states have aggressively pursued implementation of the Act under Corps regulatory oversight. The natural resource agencies in two-thirds of the coastal United States hold over 90 percent of the permits for manmade reef structures. However, since the Corps is a highly decentralized agency that leaves regulatory interpretation to the district offices in which permits are processed, there is no unified national approach to processing and approving of Corps permits for reef construction. There are no Corps permits specific to manmade reefs. Such activities are permitted under standard dredge and fill and general permits. Loopholes still exist among these Corp permits which could allow irresponsible reef development. The majority of issues addressed by this document stem from this fact. Responsible state agencies have assisted the Corps and other affected agencies in keeping such activities to a minimum and preserving long-term benefits to associated fisheries.

A few significant deviations from the format of the Plan of 1985 are contained in this report. The most significant occurs in the section dealing with materials. Materials used to construct manmade reefs are under continuous examination and evaluation by reef developers and environmental regulators. This is especially true for those materials which were originally intended for another purpose. These materials are referred to throughout as "secondary use" materials. This changes prior nomenclature for such materials previously referred to "materials of opportunity." Detailed advice on the use of various materials is deferred to a companion document developed by the commission committees that will be subject to more frequent updates as new information necessitates. Currently, no federal agency provides any form of certification of material against established environmental standards. This document does not explore this issue in detail. Much original text remains, describing the roles of relevant federal agencies when the Plan was implemented in 1985. Current administrations will interpret and clarify such roles under existing statues. Therefore, relevant statues are cited in applicable sections. Interpretation of these statues has been left to the respective agencies and the Congress. Also, coordination among the responsible federal agencies in the five cabinet level departments specified in the Act remains to be worked out.

Several critical issues of national importance provide the focus for much of the debate regarding manmade reef activities. These include the permit programs of the Corps, materials criteria, liability, research and evaluation, site location, and the roles of affected federal agencies. Further, the regional fisheries management councils established under the Magnuson-Stevens Sustainable Fisheries Act may have additional responsibilities not addressed herein that may result in further clarification of their role in conserving essential fish habitat.

One of the main areas of emphasis was to include language to reiterate the importance of manmade structures as a fisheries management tool. The basic precept to employ reefs as management tools is for the states to have at least an option of first denial to hold permits for any proposed project. Such governmental fisheries management agencies are the only entities that can demonstrate long term commitment and responsibility to the resource and resources users. These agencies are critical to establishing and maintaining compatibility with fishery management objectives for affected species.

The states also may be the only entities that can demonstrate an ability to assume liability for projected life of structure not just for the duration of the permit.

There has not been extensive use of manmade reefs in mitigation projects. However, concerns still exist regarding such applications among many state reef managers. Although some mitigation projects have successfully incorporated manmade reef structures into project objectives, extreme caution must be exercised in such instances. There is no general acceptance of the utility of manmade structures in mitigation projects.

Establishment of baseline evaluation and monitoring programs remains an issue. Recommendations for evaluation and monitoring must include assessments of physical attributes of the reef structure as well as biological attributes of species assemblages, among others. Such assessments must be measured against the objectives established for building the reef and may require that such objectives be included in permits.

INTRODUCTION

The National Fishing Enhancement Act (Act) of 1984 (Title II of PL 98-623) directs the Secretary of Commerce to develop and publish a long-term National Artificial Reef Plan (Plan) to promote and facilitate responsible and effective artificial reef use based on the best scientific information available. As defined in Section 206 of the Act, the term artificial reef refers to "... a structure which is constructed or placed in waters covered under this title for the purpose of enhancing fishery resources and commercial and recreational fishing opportunities." The term "waters" is defined as "...the navigable waters of the US and the waters superjacent to the outer continental shelf as defined in section 2 of the Outer Continental Shelf Lands Act...to the extent such waters exist in or are adjacent to any State." So defined, the Act does not exclude freshwater. However, the Plan focuses on application of artificial reefs in marine and estuarine environments.

The Plan was implemented in 1985 to provide guidance and/or criteria on various aspects of artificial reef use, including types of construction materials and planning, siting, designing, and managing artificial reefs. It included a review of information sources and discussed research needs that had been identified at that time. Other issues, such as liability and mitigation, also were introduced. These issues were to be addressed in more detail by groups of knowledgeable individuals from the federal, state, university, and private sectors. As such, the Plan is intended to serve as a dynamic, working document to be revised and updated periodically, as new information becomes available.

This revision incorporates new language developed from input received from relevant federal and state agencies, the Interstate Marine Fisheries Commissions (IMFCs), Regional Fishery Management Councils (FMCs), recreational and commercial fishing interests, and the general public. Much of the original text and format has been maintained where appropriate and pertinent to current issues, as well as to the current state of marine artificial reef development, management, and regulation in the US.

The 1985 document was general in scope and provided a framework for regional, state, and local planners to develop more detailed, site-specific artificial reef plans sensitive to highly variable local needs and conditions. Coastal states have used the Plan to develop state-specific plans under the cooperative leadership of state agencies and IMFCs that are responsible for fisheries management and development. Those plans focus on specific criteria for reef development and management in their geographic areas.

Increasing demands on fish stocks by both commercial and recreational fishermen and losses of aquatic, rough, or hard bottom habitat due to development and pollution, have had substantial effects on many reef-associated fish species. Properly constructed, artificial reefs can enhance fish habitat, provide more access to quality fishing grounds, benefit fishermen and the economies of shore communities, increase total fish biomass within a given area, and provide managers with another option for conserving, managing and/or developing fishery resources.

Artificial reefs have been used for centuries to enhance fishery resources and fishing opportunities. However, the US has not systematically developed the potential of this fishery management technique for fishery resource and habitat enhancement. Unlike Japan, which has invested billions of dollars in developing sophisticated techniques to create new habitat and increase seafood production, the US generally has pursued a less sophisticated, opportunistic, and more frugal approach. Since development of the Plan in 1985, most efforts in the US have been focused on enhancing access to fishery resources. Prior to 1985, reef development projects used natural or scrap materials almost exclusively because of their relatively low cost and ready availability. With increased funding assistance through expansion of the US Fish and Wildlife Service Federal Aid in Sport Fish Restoration Program, and with increased support from state resource management agencies, most coastal states have been able to better plan and execute more efficient and effective marine artificial reef development activities. Many coastal states now are taking advantage of more advanced technologies and methodologies to design materials and structures for specific fisheries management objectives.

Since adoption of the Plan in 1985, the majority of marine artificial reef development has come under the auspices of individual state programs and/or state plans. During this time, many states and the US Army Corps of Engineers (Corps) have entered into regional partnerships or effective local working relationships resulting in better implementation of the provisions of the Act under the guidance of the Plan. In this regard, the Plan has functioned well and generally has been deemed a success. However, growing concerns over the adequacy of the Plan to meet current and future demands being placed on reef developers and fisheries managers mandates revisions based on current information and the experiences of reef developers and fisheries managers. Development of marine artificial reefs outside of approved state programs or plans, or without the supervision of experienced state developers or state and federal fishery managers, still poses a concern. Of particular concern are reef deployments in or adjacent to waters which are not covered by an approved state-specific artificial reef management plan, or where inadequately staffed and trained local coastal governments manage reef programs. Improperly located reefs, built out of inappropriate materials or built under inadequately reviewed permits can pose long-term problems. These are critical factors, which continually need to be revisited in the Plan to clarify the roles for proper state and federal involvement in this national activity and assure optimal use for artificial reefs in the US.

Although artificial reefs can enhance recreational and commercial fishing opportunities, creating a successful reef entails more than placing miscellaneous materials in ocean, estuarine, or other aqueous environments. Planning, long term monitoring, and evaluation measured against project goals and objectives must be incorporated into each project to ensure that the maximum anticipated benefits are derived from artificial reefs. Improperly planned, constructed, or managed reefs can be ineffective, can cause conflict among competing user groups and activities at the reef site, increase the potential to overharvest targeted species, or may damage natural habitats. In such cases the benefits from the planned objectives of these structures may not be realized or may be negated.

The Plan provides guidance emphasizing the use of the most recent and best information available for effective and responsible development of artificial reefs for long-term fishery enhancement. It is intended to address the needs of a wide variety of users, including reef regulators, fishery and environmental managers, prospective donors of reef material, government officials, and the general public. The Plan addresses both criteria specified in section 204 of the Act, and unspecified criteria considered important by the working groups providing input to this Plan. The consideration and use of these guidelines and criteria will assist reef developers, managers, and regulators in focusing their activities on effective artificial reef programs and performance monitoring. It establishes standard terminology to improve communication between parties interested in reefs, and assists in developing more uniform permitting procedures and clear guidance on materials acceptable for construction of marine artificial reefs.

Artificial reef development and management protocols and guidelines contained in the Plan are designed to enhance the use of artificial reefs as fisheries management tools. In this regard, artificial reefs should, at a minimum, cause no harm to existing living marine resources and habitats. Optimally, artificial reefs should be developed such that aquatic resources and habitats are enhanced. As a fisheries management tool, objectives of the artificial reef project should match or compliment objectives of state, interstate, and federal fisheries management plans (FMPs) for affected species, and be compatible with other management tools contained in such FMPs (e.g., gear restrictions and area closures).

NATIONAL STANDARDS FOR ARTIFICIAL REEF PROGRAMS

The purpose of the National Fishing Enhancement Act is to promote and facilitate responsible and effective efforts to establish artificial reefs in the navigable waters of the US and waters superjacent to the outer continental shelf (as defined in 43 USC, Section 1331) to the extent such waters exist in or are adjacent to any state. Section 203 of the National Fishing Enhancement Act establishes the following standards for artificial reef development. Based on the best scientific information available, artificial reefs in waters covered under the Act "…shall be sited and constructed, and subsequently monitored and managed in a manner which will:

1) enhance fishery resources to the maximum extent practicable,

2) facilitate access and utilization by US recreational and commercial fishermen,

3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters,

4) minimize environmental risks and risks to personal health and property, and

5) be consistent with generally accepted principles of international law and shall not create any unreasonable obstruction to navigation."

ROLES

The roles of all parties involved in artificial reef development, management, and regulation outlined in the original Plan have evolved significantly since 1985. The Corps has formalized their involvement through regulations promulgated pursuant to the Act (see "Regulatory Requirements"). Involvement on a state level varies, with most coastal states having some degree of control or oversight of artificial reef development in their waters and adjacent federal waters. Most Atlantic and all Gulf of Mexico states also participate in regional communication and coordination concerning essential artificial reef management activities through their respective IMFCs. The general consensus of state reef program managers is that artificial reefs are fisheries management tools, and as such, their use constitutes a fisheries issue that must be addressed accordingly.

Unique partnerships in artificial reef development between state, federal, and private interests have formed over the past 12 years with the states as the lead fishery management agencies and the primary entities in implementation of the Plan. Close interaction between the Gulf States and Atlantic States Marine Fisheries Commissions and the National Marine Fisheries Service facilitated the current revision of the Plan.

Federal

The federal role is to provide technical assistance, guidance, and regulations for the proper use of artificial reefs. Such assistance must be compatible with other long-term needs, and should improve coordination and communication between the federal agencies, states, FMCs, IMFCs, commercial and recreational fishing interests, diving communities and other interested parties. Generally, the federal role is carried through the permit process. Additionally, federal agencies may provide guidelines, services, information, financial aid, and in-kind support for some projects. Federal fisheries agencies may provide some regulatory functions regarding fishing practices on specially designated artificial reefs (e.g., "Special Management Zone" (SMZ) designation in the South Atlantic and Gulf of Mexico FMC FMP for snappers and groupers, and reef fish, respectively).

The Federal Government has been involved in artificial reef activities for several decades, both in research and development sponsored by individual agencies, and in reviewing and commenting on reef permit applications (see Act section 205). There is, however, no overall federally coordinated program to guide artificial reef activities except through the permit program of the Corps of Engineers. The President's Proclamation of an Exclusive Economic Zone (EEZ) on March 10, 1983 declared a national (federal) interest in living and non-living resources found within 200 nautical miles from shore. In addition, the National Recreational Fisheries Conservation Plan of 1996, developed pursuant to Executive Order 12962 - Recreational Fisheries, directs specific federal activities to utilize artificial reefs in implementation of a national recreational fisheries resources conservation plan. The Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Fisheries Act) (PL 103-206) of 1993, finds that: "...increasing pressure, environmental pollution, and the loss and alteration of habitat have reduced severely, certain Atlantic coastal fishery resources...and...It

is the responsibility of the Federal Government to support...cooperative interstate management of coastal fisheries." Increased use of fisheries resources is expected in the EEZ, and there undoubtedly will be more interest in the use of artificial reefs to enhance these resources and the habitats essential to their proliferation.

Five federal entities -- the US Departments of the Interior (DOI), Commerce (DOC), Defense (DOD), and Transportation (DOT), and the Environmental Protection Agency (EPA) -- have varying degrees of interest in, and responsibility for, artificial reefs.

Department of Interior

The DOI has broad authority under the Outer Continental Shelf Lands Act (OCSLA) to protect natural resources. They have specific responsibility to enhance recreational fishery resources under the Federal Aid in Sport Fish Restoration Act of 1950 (Dingell-Johnson Act) as amended by the Wallop-Breaux Amendment, through the Deficit Reduction Act of 1984 (PL 98-369, USC 777c). This act provides federal financial assistance to the states for approved studies and projects directed at enhancement of recreational fisheries resources.

The US Fish and Wildlife Service

The US Fish and Wildlife Service (USFWS) administers the Federal Aid in Sport Fish Restoration Program which provides matching grants to the states to undertake sport fish restoration and boating projects. Money for this program is collected from excise taxes on fishing tackle and motor boat fuels in a "user-pays/user-benefits" program. The 1984 Wallop-Breaux Amendment to the Sport Fish Restoration Act significantly enhanced the states' abilities to undertake artificial reef programs through increases in financial assistance for such projects. Consequently, this funding has influenced the direction of artificial reef programs nationwide with a greater focus on enhancement of recreational fisheries and increased fishing opportunities through better access to the fisheries resources.

In addition, the USFWS participates in the cooperative Interstate Fishery Management Program (ISFMP) of Atlantic States Marine Fisheries Commission (ASMFC) to develop and implement fishery management provisions of the Atlantic Coastal Fisheries Act. The USFWS also provides a critical function in co-chairing the National Recreational Fisheries Resources Conservation Council with the National Marine Fisheries Service.

The Minerals Management Service

The Minerals Management Service (MMS) is responsible under the OCSLA for leasing federal lands on the US outer continental shelf (OCS) and regulating the development of oil, gas, and sulfur resources in an orderly manner while properly safeguarding the environment. The MMS supports the appropriate conversion of retired platforms for reefs when such platforms are permitted and designated for use by a state artificial reef program and within areas established for receipt of platforms for the enhancement of habitat for fish and other aquatic life.

Department of Commerce

The National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) carries out responsibilities of the DOC in regard to marine fisheries of the US. The DOC has responsibility under the Magnuson Act as amended by the Sustainable Fisheries Act of 1996, to restore, maintain, and enhance fishery resources in the EEZ. Also under this act, the DOC must develop and provide to FMCs, guidelines on essential fish habitat (EFH) which will assist in amending fishery management plans developed by the FMCs. Under these new provisions, artificial reefs may be designated as essential fish habitat. The DOC also has general authority under the Fish and Wildlife Act of 1956 and the Interjurisdictional Fisheries Act 1989 (PL 99-659) to cooperate with the states to conserve and manage fishery resources in the territorial sea. Further, under Section 804 of Atlantic Coastal Fisheries Act, the Secretary of Commerce, in consultation with the Secretary of Interior, "...shall implement a program to support interstate fisheries management efforts...[which]...shall include habitat conservation..."

Further, the Maritime Programs Appropriations/Authorizations Act of 1972 (PL 98-402) authorized the transfer of surplus World War II "Liberty" class war vessels designated by the Secretary of Commerce to coastal states as scrap if states would utilize them to construct artificial reefs. Provisions of this act established a formal protocol to remove derelict vessels from the Maritime Administration's inactive fleet and transfer them directly to state artificial reef programs. Such vessels have been utilized by many state marine artificial reef programs over the years, and have provided excellent fishing and diving sites. The National Fishing Enhancement Act amends this act to transfer authority for vessels available for artificial reefs to the Department of Transportation. However, some constraints may exist on availability or suitability of military vessels for artificial reef use.

The NMFS also plays an obvious part in artificial reef development, management, and regulation through its role as the lead agency in the development of the Plan. Additionally, the NMFS has been involved in a general oversight capacity in such activities as providing comments on artificial reef permits, research, establishment of acceptable standards for the transfer, cleaning and preparation of certain reef materials, and in establishment of fishery regulations pertaining specifically to development of artificial reef sites.

The National Ocean Survey

The National Ocean Survey (NOS) of the National Oceanic and Atmospheric Administration plays a role in mapping the locations of artificial reef sites and other bottom obstructions in cooperation with fishermen. Due to the advent of affordable differentially correct global positioning systems (GPS), many coordinates of previously marked artificial reef sites have been found to be inaccurate. During the Corps permit process, the NOS must be notified of reef locations to ensure that reef sites are accurately plotted. Cooperative programs with fishermen and/or divers may be of great value as part of the monitoring of permitted reef sites by assisting in detection of any movement or deterioration of reef structures and components.

Department of Defense

The DOD is responsible for preserving national security, maintaining navigation, and protecting the public interest in multiple uses of the Nation's waters. The DOD has worked with the states in several programs to provide materials for reef construction. More recently, the ReefEx initiative was developed within several branches of the DOD to facilitate transfer of demilitarized combat vehicles to state artificial reef programs along the Gulf and Atlantic coasts. Although the program is now inactive, the intent was to make other suitable materials available in future program elements.

The US Army Corps of Engineers

The US Army Corps of Engineers (Corps) is responsible for regulating certain activities in waters of the US under Sections 9 and 10 of the Rivers and Harbors Act of 1899 (RHA). They also have permit authority under Section 404 of the Clean Water Act (CWA), and Section 103 of the Marine Protection, Research and Sanctuaries Act (MPRSA). The Corps regulates work on structures under the RHA and the transport of dredged material under the MPRSA. Specifically, the Corps is the lead federal agency responsible for permitting and monitoring artificial reef development under authority of the National Fishing Enhancement Act of 1984. Pursuant to Section 203 of the Act, the Corps promulgated rules for permitting artificial reef development activities in 33 CFR, Parts 320 through 330, November 13, 1986. The Corps and EPA share responsibility for regulating the discharge of dredged or fill material under the CWA.

The Department of Transportation

U. S. Coast Guard

The DOT through the US Coast Guard (USCG) has authority to: 1) promulgate regulations dealing with lights, warning devices, and other public and private aids to navigation on offshore installations, 2) establish safety fairways and traffic separation schemes for safe movement of vessel traffic under the Ports and Waterways Safety Act, 3) establish safety zones around offshore facilities, 4) enforce fishery laws, and (5) monitor and enforce compliance with international conventions and statutes on environmental protection.

Maritime Administration

Also within the DOT, the Maritime Administration has been involved in numerous artificial reef construction projects over the past three decades through the donation of surplus ships for reef construction material. Under amendments to PL 98-402 in Section 207 of the National Fishing Enhancement Act, the Secretary of Transportation has authority to designate any “obsolete” vessel as being available for transfer to state artificial reef programs.

The Environmental Protection Agency

The Environmental Protection Agency (EPA) has responsibility under MPRSA and the CWA to regulate ocean dumping and point source pollution. All permits issued under these two Acts must comply with environmental guidelines promulgated by EPA. Under the MPRSA,

EPA also has authority to designate ocean dumping sites for all discharges into ocean waters. However, such activities have been segregated in EPA permits from artificial reef construction activities. Under the CWA, EPA co-administers the Section 404 program with the Corps. Otherwise, the EPA does not permit artificial reef construction. Among other responsibilities, EPA may prohibit or restrict discharges of dredged or fill material at sites where the discharge would have unacceptable effects on fish, shellfish, wildlife, recreation, or municipal water supplies. Although the EPA has not developed general guidelines for materials used in constructing artificial reefs, it has dealt with specific materials. As part of their involvement in ReefEx, the EPA developed criteria for preparation of de-militarized combat vehicles prior to their use in reef construction. Although specific to this particular material, this marks the first time since passage of the National Fishing Enhancement Act of 1984 (PL 98-623) that the EPA has provided such guidance or standards for artificial reef materials.

State

State Natural Resource Agencies

Virtually all state natural resource agencies with active marine fisheries management and enhancement programs are involved in artificial reef activities. Since implementation of the Plan of 1985, most state marine fisheries agencies have assumed the lead in acquiring permits, maintaining liability, financing, constructing, researching, and monitoring marine artificial reefs through state supported programs. Other involvement ranges from artificial reef construction as part of an agency's efforts to improve a specific fishery, to an agency's review and support for other organizations' reef building programs. The level and type of state involvement in an artificial reef program is usually governed by the following factors:

1) the need to offset fishery or habitat stress with habitat enhancement,

2) the degree of public support,

3) constituency pressures to enhance access to fisheries, and

4) the availability of a stable funding source to support reef construction.

Since adoption of the Plan in 1985, many coastal states have adopted state-specific plans based on its guidance. In effect, the states have been responsible for implementing the Plan and collecting information necessary for updating guidance in the Plan, and for strengthening provisions of the National Fishing Enhancement Act of 1984.

State resource managers recognize that benthic artificial reef construction involves long-term, if not permanent, alteration of bottom habitat. As such, possible effects on natural resources and the environment must be considered prior to construction. Some past artificial reef construction projects which were used largely to justify solid waste disposal, were not well-researched regarding specific resource or fishery enhancement problems, did not have specific

fisheries management objectives, and would not be acceptable under present artificial reef development policies or philosophies. There is general consensus among state agencies that artificial reef projects must be considered as fishery management issues. Species and fisheries associated with marine artificial reefs typically have been predominant in federal waters. As more of these species become subject to IMFC FMP regulations, it is important that state artificial reef programs become more closely linked organizationally with state fishery management programs. In order to achieve the greatest benefits from man-made reefs, it is imperative that appropriate state agencies play a major role in the development of national and site-specific guidelines for their use.

Because of the potential long term effects of altering the environment through artificial reef development, and the potential impacts of artificial reefs on finfish and shellfish stocks, eligibility to hold a permit to develop an artificial reef should be restricted to the appropriate state fishery management agency. The states' natural resource agencies hold the public trust in managing resources associated with artificial reefs and are the principal entities which can demonstrate long-term accountability for liability required in artificial reef permits. The state agency or representative of a state agency may wish to further delegate this authority. If the state wishes to extend its permit authority to other entities, it should do so in writing to the appropriate District Corps office. However, the state agency should be the ultimate authority for artificial reef development and management activities. States without state-sanctioned artificial reef programs and/or state artificial reef plans should direct development of artificial reefs through the state marine fisheries resources agency to assure consistency with fishery management objectives.

The role of the states in the artificial reef construction process is to develop or participate in developing statewide and site-specific plans. Further, such plans should be designed to maintain regulatory and quality control that ensures all reef construction:

1) has a specific objective for fisheries management or other purpose stated in the goal of the state-wide, site-specific plan,

2) has biological justification to meet present and future fishery management needs,

3) minimizes negative effects on existing fisheries, and/or conflicts with other uses,

4) minimizes negative effects on other natural resources and their future use,

5) uses materials that have long-term compatibility with the aquatic environment, and

6) subsequently is monitored to determine if reefs meet permit terms and conditions and the original enhancement justification and objectives.

State natural resource agencies should be involved in all artificial reef construction in their waters, and should also have a major influence on artificial reef development in adjacent federal waters, due to contiguous and shared fishery and resource management concerns.

When artificial reef construction projects go beyond state government limitations (e.g., financial or regulatory), state natural resource agencies should at a minimum, provide guidelines, policies, and acceptable procedures to assist other responsible organizations undertaking artificial reef projects, if artificial reef development activities are desired by the state.

Interstate Marine Fisheries Commissions

Coastal states have, in effect, assumed the responsibility for implementation of the 1984 Act, and have coordinated associated activities through their respective IMFCs. The coastal state agencies have acted responsibly in developing state programs accountable to federal directives, as well as to local and regional needs. Coordination of state efforts through the IMFCs has facilitated a dynamic and positive evolution of national artificial reef efforts. The cooperative efforts of state reef developers have progressed beyond a focus on solely creating access to fisheries utilizing materials of opportunity. The states have utilized the tools given them in a responsible and innovative manner to validate methodologies in reef research on such topics as construction and siting, fishery management, regulatory requirements, and reef biology (including production and aggregation issues). Such validation is essential for effective use of marine artificial reefs in fishery management planning, restoration or development of essential fish habitat, and to demonstrate innovative alternatives for which artificial reef structures can be useful.

The role of the IMFCs is to provide an open forum for discussion and debate on issues facing state artificial reef program managers, respective federal agencies, and affected fisheries interests. States along the coasts of the Atlantic and Gulf of Mexico established technical advisory committees for marine artificial reef development within their respective IMFCs. These committees are composed of the coordinators of the state marine artificial reef programs within the state agencies responsible for marine and coastal resources management. Committee membership also includes representatives from the NMFS, the US Fish and Wildlife Service, the MMS, the EPA, and the FMCs. These committees provide critical advice to the IMFCs relative to development of marine artificial reefs, and have served to increase responsiveness and efficiency of coastal artificial reef programs.

The Artificial Reef Technical Committees of the Atlantic and Gulf States Marine Fisheries Commissions meet periodically to exchange information and to coordinate activities relevant to common areas of interest. Joint committee activities have served to consolidate individual state efforts along the Atlantic and Gulf coasts, thus assisting in implementation of key elements of the Act. The committees have worked cooperatively to identify and resolve national issues such as standardized criteria for materials used to build artificial reefs. The joint committee forum also has assisted member states in development and implementation of individual state plans and policies responsive to local, regional, and national needs. Coastal states should continue such coordination through the relevant bodies of their respective IMFCs.

Local Governments (County and Municipal)

Local government agencies have been involved in directing or coordinating artificial reef programs. Their role has included coordinating programs to provide materials for reef construction; providing technical support or supervision for community efforts; conducting reef programs, including financial support; obtaining state monies for local reef efforts; and publicizing local reef efforts. These efforts should be conducted under the oversight of state fishery management agencies to ensure compatibility with established state, regional, and national fishery management goals. As part of the economic development activities of local chambers of commerce, local governments should assist state artificial reef programs in collection of relevant social and economic information. Such information is extremely important in developing goals and objectives for reefs.

Private

Many artificial reefs constructed in the years prior to enactment of the National Fishing Enhancement Act of 1984 were initiated by individuals, sport fishing clubs, local artificial reef committees, and diving clubs. Private groups and organizations played an important role in artificial reef development during this time. They communicated the needs of fishermen, lobbied for the development of local and state artificial reef programs, and undertook fund raising activities. In addition, private individuals and clubs often provided volunteer services for the cleaning, modification, construction, transportation, and deployment phases of artificial reef projects. Under the supervision of biologists, local divers have contributed to monitoring and evaluation studies. Such activities have encouraged entrepreneurial ventures by private interests in development of artificial reef materials and designs.

Although these groups have traditionally played an important role in development of artificial reefs in many states, they should coordinate their activities with state artificial reef programs or state marine fishery resources agencies to ensure such reefs are used properly and in compliance with all pertinent regulations and management goals. Also federal, local, and university expertise should be sought to achieve the most successful reef projects. Without this interaction, reef development should not be permitted. Further, eligibility to hold an artificial reef permit should be restricted to the state agency responsible for managing marine fisheries resources. These agencies are the only entities that can be expected to maintain long-term management and accountability of liability on permitted sites.

Recent developments in the private sector should help resolve some of the problems reef builders have had in initiating programs. Several companies now provide expertise in artificial reef development, as well as effective materials for construction of artificial reefs and coordination of volunteer efforts. Other companies, non-profit organizations, universities, and consortiums may add expertise in this area as well. Some private reef developers have been innovative in working with state artificial reef programs by not only providing innovative materials and designs for reef construction but also locating financial assistance and volunteer labor for deployment activities and monitoring.

GUIDELINES

Siting

Proper siting is vital to the overall success of an artificial reef. The initial focus should be to enhance or create viable habitat that will benefit fisheries associated with the reef material and design. The goal and/or objectives of the artificial reef project, social and economic considerations, and environmental and biological concerns must be identified early in the planning stages. Reefs that are improperly sited and do not take all of these factors into consideration during the planning phase will result in wasted time, money and effort and will not fully realize the objectives. Improperly sited reefs can also result in a number of negative impacts including hazards to navigation, damage to naturally productive bottom, and environmental clean-up problems. Such ill-conceived projects should not be permitted. The following guidelines are provided to assist reef builders in the critical site-selection stage of artificial reef development.

Purpose

Traditionally, the majority of artificial reefs in US coastal marine waters have been sited and built to support and enhance recreational fishing. Other uses undoubtedly will be considered as fishery stocks come under increasing pressure. Properly sited, constructed and managed reef sites, particularly multiple-site complexes, can meet a variety of uses. However, all of these uses should share the common purpose of enhancing the marine habitat for associated fishes and other organisms. The fundamental issue dictating the design and location of an artificial reef is its intended purpose(s) or objective(s). Failure to clearly identify the objective(s) of a reef at the outset, and to use reef purpose(s) as the driving force for subsequent reef siting, design, construction, and management decisions, can detract significantly from overall reef effectiveness and utility, and compromise public confidence in artificial reef programs.

State and federal fishery management agencies, FMCs, and other natural resource management entities have established essential protocols for siting artificial reefs. Those outside of these entities with an interest in building artificial reefs should contact the relevant state agency to obtain pertinent background information, (i.e., biological, socioeconomic, and regulatory) to identify the best procedure for advancing a proposed reef building project. These agencies should work together to identify commercial and recreational fishing interests which must be considered in the planning process from the outset. Also, they should ensure open lines of communications exist to avoid potential conflicts among user groups.

While the majority of reefs have been built to support and enhance fishing, there is growing interest in using artificial reefs to restore, mitigate, or create habitat, to improve recruitment, and enhance juvenile survival and growth of reef associated species. The following factors should be considered in siting reefs to accommodate fishing activities, and to enhance fish.

Habitat Enhancement and Creation

Prospective reef builders should have an understanding of the limiting factors involving the fauna and flora that will utilize an artificial reef site. Builders must identify the habitat type and/or species targeted for enhancement and determine which biological, physical, and chemical site conditions will be most conducive to goal attainment. Once these siting criteria are determined they should be used in identifying potential construction sites and materials to be used.

Artificial reefs should not be constructed on many types of natural habitats, such as:

1) existing coral reefs,

2) significant beds of aquatic grasses or macroalgae,

3) oyster reefs (except for shell stock replenishment),

4) scallop, mussel, or clam beds, or

5) existing "live bottom" (marine areas supporting growth of sponges, sea fans, corals, and other sessile invertebrates generally associated with rock outcrops).

In some cases, however, it may make sense to construct artificial reefs in areas with sparse "live assemblages" or on barren bottoms in proximity to biologically productive areas. This can be done to enhance the area and/or to divert user pressure from fragile natural areas.

Recreational Fishing Enhancement

Prospective reef builders should understand the nature and extent of recreational fishing in the area when planning artificial reefs for recreational fishing enhancement. Particular attention should be given to assessing the relative importance of, and demand for, shore-based and boat-based fishing activity. The national Marine Recreational Fishery Statistics Survey (MRFSS) or similar state surveys could provide such information. Other factors that must be considered include:

1) location of shoreline access points (e.g. ramps, piers, marinas, bridges, and charter and party boat docks),

2) general fishing methods and use patterns (e.g. trolling versus bottom fishing, vessel sizes, distances traveled offshore, skin and SCUBA diving), and

3) potential conflicts with other users (e.g. commercial fishermen, divers, shipping, general navigation, military, mineral and energy extraction, historic wrecks and sites, etc.).

State and local government-sponsored artificial reef programs should attempt to accommodate the full range of recreational fishing needs. In addition to providing for the

needs of boat-based anglers in offshore and inshore waters, artificial reefs should be considered to enhance or maintain recreational fishing from bridges, piers, jetties, and other shoreline locations. State and local cooperation is vital to assure the stability of materials used and to avoid potential conflicts. Enhancement of shore-based angling can have particular social and economic significance to coastal communities with heavy tourist traffic and can help to expand public support for artificial reef development. Caution should be exercised when developing artificial reefs in nearshore areas due to the increased potential for spatial and use conflict. Careful project planning will minimize those conflicts.

Recreational reefs are generally used more when they are properly charted (mapped); adequately marked (buoyed); located fairly close to shore; accessible by running simple compass headings and known distances from permanently marked buoys at the mouths of major rivers, inlets, or passes; and have published coordinates. If reefs are located fairly close to shore and are not buoyed, reef sponsors should provide visual lineups with shoreline reference points (e.g., water tanks, buildings, antenna towers) to allow boaters who do not have electronic navigation equipment to find the reefs easily.

Sponsors of artificial reefs should develop and distribute public information brochures and/or flyers describing reef locations, fishing conditions at each site, applicable fishing regulations, or use restrictions. Such restrictions would include observance of diving flags, anchoring guidelines, fishing gear restrictions, catch limitations, and courtesies which should be extended to other reef users. Accurate reef information is critical to public use and benefits.

Sport Diver Enhancement and Access

Sport divers represent a growing number of artificial reef users. The development of new technology and the increased availability of diver training and access has led to a tremendous increase in the number of sport divers in the US. The economic impact of sport divers frequenting artificial reefs often rivals that of recreational fishing activities in some regions. If a state wishes to propose artificial reefs constructed for diving, there may be specific siting and construction considerations for that application.

Reefs proposed for divers should be sited and constructed at depths that will provide reasonable bottom time and minimize the decompression hazard. Factors such as water clarity, proximity to other popular dive areas, average current velocities, depth, and possible conflicts with other user groups (e.g. recreational hook and line and/or commercial fishing, navigation, etc.) should be considered.

Commercial Fishing Enhancement

The use of commercial fishing reefs could prove beneficial by providing specially designated sites for commercial fishing only. This would have the effect of reducing potential user and spatial conflicts with recreational anglers and divers. To effectively accomplish this approach, (SMZ) status through state and federal regulatory processes would be required. Another approach to this objective would be to site artificial reefs for commercial fishing activity far enough offshore or from shore-based access sites that recreational anglers and divers would not likely travel there.

As in any other application of artificial reefs, it is useful to consider the issue of habitat limitation when siting reefs for commercial purposes. The distribution of reef and reef-like habitats is sporadic, leaving large expanses of sea bottom covered by silt, mud, and sand. Such areas are typically devoid of species that are known to associate with reef habitats, including snappers, groupers, triggerfish, porgies, black sea bass, tautog, and Pacific rockfish, among others. However, many commercially important species may not be habitat limited. Instead they may be limited by impacts of fishing activities or negative environmental parameters, such as poor water quality. In these cases, artificial reefs may not enhance the net gain in catch, and may actually contribute to a decline in the total biomass.

Along with the historic practice of shell stock (cultch) planting to create or enhance oyster reefs, artificial reef technology may also be applied to the following:

1) creating and/or expanding kelp beds,

2) oysters and mussel culture,

3) enhancing the yield and survival of spiny and American lobster,

4) concentrating pelagic species to enhance harvest,

5) live rock culture,

6) providing essential habitat for associated reef fishes, and

7) culture of organisms for biomedical use.

Marine Sanctuaries

The use of artificial reefs as marine sanctuaries (either for a certain stock or for protection against all consumptive uses) has been applied in very few areas to date. However, this may be one of the most underutilized applications for artificial reefs. The idea of marine sanctuaries covering large amounts of natural live bottom areas has been debated by fisheries management agencies for several years. This idea has little support among recreational and commercial fishing interests, and has become a case of "not in my back yard." The use of newly sited and constructed artificial reefs to create marine sanctuaries could ease some of these concerns, providing hard substrate and habitat in an area of pre-existing fisheries, while leaving traditional fishing areas open.

Artificial reef managers involved in siting and constructing reefs for marine sanctuaries should, as with all reef planning, clearly identify the goals of the reef. Proper siting should take the following factors into consideration:

1) proximity to natural live bottom,

2) primary target species and associated prey species,

3) life history stages of affected species,

4) hydrological and geophysical factors,

5) enforcement,

6) traditional uses of the proposed site,

7) paths of ingress and egress to and from the site for target species, and

8) material design best suited to meet the reef objectives.

Mitigation

Artificial reefs have been employed to mitigate the destruction or degradation of various marine habitats due to development or catastrophic loss. In some instances, the application has been in-kind, on-site mitigation. In California, for example, a major power company funded construction of an artificial reef to replace kelp habitat and associated resources impacted by power plant operations. In other instances, reefs have been built a distance from the damaged area to substitute for non-reef habitat. For example, the Corps built an artificial reef in Delaware Bay as mitigation for loss of brackish water river bottom. However, it is preferable to use mitigation in-kind and as near the location of the damage as possible.

The use of artificial reefs to mitigate the loss or damage of marine habitats is a complex issue that involves more than substituting one type of habitat for another. The benefits gained from creating an artificial reef may not be the same as those derived from the natural system it is intended to replace. Whenever possible, the area in which the environmental damage might occur should be studied beforehand to discover the ecological functions provided by the existing system. Then, artificial reef technology, which will simulate those functions to the greatest degree possible, should be utilized. For example, a coral reef in Key Biscayne National Park, damaged by the impact of a large vessel, was successfully repaired using state-of-the-art technology that simulated natural coral.

When artificial reefs are proposed for non-reef related mitigation, often it is the only way to attempt to compensate for the loss of such habitat or fishery access. When faced with this situation, resource managers have two primary considerations:

1) can artificial reef technology be used to repair or replace the damaged habitat, and

2) if not, how can artificial reef technology be used to replenish specific elements of the overall resources of the area.

Social and Economic Considerations

Recognizing that the majority of artificial reefs will continue to be built to support fishing and diving activities, artificial reef development should be located in geographic areas with the

greatest user needs, demand, and constituency support. Artificial reefs constructed for recreational use normally will be near major population centers. Occasional reef construction in less populated areas may be appropriate to stimulate local economies and alleviate fishing pressure on more congested sites. Reef builders can use US census reports, together with fishing license, boat registration, and landings data to delineate recreational fishing demand centers. For commercial fishing reefs, demand centers may be more sparsely populated, but should be recognized fishing communities with the appropriate infrastructure. Artificial reefs built for divers should focus on population centers with dive charter availability or potential. Artificial reefs built for research, sanctuaries, culture of aquatic organisms, and other less user-oriented purposes will require siting criteria more specific to those uses. Further, it may be appropriate to avoid population centers for these types of reefs for best results.

Within each of the user demand centers identified, land and water access systems should be evaluated. Reefs should be planned in areas where there are adequate public access facilities and infrastructure support. Recreational reefs should be located for safe access by prudent anglers and divers, and in locations easily supported and maintained by reef managers. Studies of recreational use patterns can be particularly useful in this endeavor. Reefs for commercial fishing can be sited further from harbors and inlets, but energy conservation should remain an important consideration. Reefs installed as reserves, sanctuaries, nursery areas, or spawning habitats should be located or managed to minimize fishing pressure, yet allow for adequate enforcement.

Before beginning the site selection process, reef planners should determine existing fishing patterns and conditions offshore of each identified demand center in question. Such information should include:

1) an estimate of reef use,

2) preferred target species,

3) distances from nearest navigable inlet or harbor,

4) traditional fishing areas and methods, and

5) existing or future fishery management issues which may affect the reef site or users (e.g., stock status problems, user conflicts, closures, etc.).

Analysis of this information should enable prospective reef builders to delineate broad geographical areas adjacent to identified demand centers within which to begin a more detailed site selection process and should help determine reef size and management needs. The size (areal extent) of a reef can be important, depending on the type and quantity of material to be used and the number of boats expected on a reef at any one time.

The goals and priorities of the reef managers should direct overall site selection. Within the identified target area, existing artificial reefs and known bottom obstructions should be identified. Exclusion areas should include, but need not be limited to:

1) shipping lanes,

2) restricted military areas,

3) areas of poor water quality (e.g., low DO, dredge spoil sites etc.),

4) traditional trawling grounds,

5) unstable bottoms, existing rights-of-way (e.g., oil and gas pipelines and telecommunication cables), and

6) sites for other purposes that are incompatible with artificial reef development.

Environmental Considerations

When the intended artificial reef construction purpose is clearly established, the following should be established and addressed:

1) evaluation of social and economic siting concerns,

2) definition of a general reef construction target area,

3) delineation of known exclusion areas, and

4) assessment of proposed site geology, hydrology and water quality.

Information and assistance useful to these assessments can be obtained from state and local natural resource management agencies, academic institutions, private consulting firms, not-for-profit organizations, and local residents. Specific attention should be given to the points covered below.

Bottom Geology

The bottom composition and character at an artificial reef site has a pronounced effect on reef stability and longevity and must be carefully evaluated in the site selection process. In most cases, soft sediments such as clays, silts, and loosely packed sands should be avoided. Over time, most reef materials may sink into these sediments or become partially covered, thereby losing their utility as fish habitat.

Bottoms consisting of hard rock or hardpan with a veneer of sand cover provide excellent substrate for most types of reef construction. Dense materials such as concrete cannot settle or scour excessively on these substrate types. Reef planners should be aware however, that

bottom sediments shift and may change radically during storms, hurricanes, and geologic events. Materials that present large amounts of surface area may scour deeply into almost any bottom type, depending upon storm events, current, or wave.

Excessive silt and sand may become detrimental to the epibenthic organisms associated with artificial reef structures, covering or burying them. Water column sediment loads may reduce the fouling community by reducing light penetration.

Estimations of depth and bottom type using NOS charts are recommended only in the planning stages for a new reef site. Detailed information about bottom type and water depth should be obtained before a site is actually permitted for development of artificial reef construction.

Hydrography

Principal hydrographic factors to be considered in selecting sites for artificial reef construction include water depth, potential wave height, currents, and tides. Water depth is significant as a criterion for siting, for several reasons. First, reefs must be built in water sufficiently deep to avoid creating a hazard to navigation. Minimum clearance above the reef should accommodate the draft of the vessels expected to operate in the vicinity. The USCG and the Corps will review the merits of each reef construction proposal in light of local circumstances (see Regulatory Requirements section). Factors considered in these cases include water depths at and near the site, type of construction materials to be used, reef clearance, nature and extent of vessel traffic in the area, and proposed marking methods.

Second, water depth has implications for reef users. In many coastal areas, water depth is a function of the distance offshore. This relationship must be considered when making tradeoffs between reef stability, clearance requirements, target species, and reef accessibility to various user groups (e.g., small versus large boat fishermen, commercial versus recreational fishermen, fishermen versus divers).

Third, water depth affects species composition at the reef site. This includes all sessile and motile invertebrates associated with the reef as well as plant life and fish assemblages. Reef materials placed in clear or shallow water with good light penetration generally will provide the best results in meeting the typical biological objectives of most artificial reef projects. Water depth is a key factor in determining the likely presence of desired life history stages of target fish species. Also, water depth at the reef site may critically affect reef material stability and long-term structural integrity. In this case, average wave energy in large, open bodies of water as a function of water depth is the major concern.

The magnitude of wave interaction with a reef is difficult to predict but it can be destructive. It is primarily dependent on wave height, wave speed, depth of the reef, and density and shape of the reef material.

This force can resuspend bottom sediments causing siltation on the reef or destabilization of reef materials allowing them to move short distances or entirely off the site. Reef materials

and designs should be properly matched to water depths and predicted wave conditions to ensure their stability. Planning for worst-case storms may need to be considered on sites where movement of materials would be detrimental or hazardous.

Predicted currents (tidal or wave-generated) for a possible reef site can greatly influence reef effectiveness as well as necessitate inclusion of certain critical design parameters in the selection of reef materials. Reefs should be designed to resist breakup, movement or burial that might result from the effects of currents. Detailed engineering studies may be required in some cases to ensure reef success in some areas.

Currents also influence reef effectiveness and the number of boats that can fish a reef at one time. Fishing reefs constructed across prevailing currents will allow the maximum flow of nutrient/food-laden, well oxygenated water through the reef and increase the availability of food for reef organisms and may improve hatching success of adhesive egg masses. This design orientation also helps create nutrient upwelling over the reef which, if large enough, attracts and concentrates baitfish and their predators which are often targeted by fishermen. In spite of the possible advantages of orienting reefs perpendicular to general current directions, there are cases (exceptionally strong currents or predictable storm surge) where restrictions to water flow should be minimized. In these cases, structures might function better if oriented parallel to or at shallow angles to predominant current flow or direction of storm surge.

Water Quality

General water quality is another important reef siting consideration. Water turbidity, salinity (in estuarine and coastal areas), dissolved oxygen, biological oxygen demand, water temperature, nutrient loads, pollution levels, and other water quality factors affect both the biological productivity and use value of artificial reefs. For example, benthic reefs built in areas with low dissolved oxygen levels (generally below 3mg/l) or where anoxic (oxygen-depleted) conditions periodically occur will not achieve desired biological productivity levels and will probably not achieve management goals. Similarly, reefs built in highly turbid water would have limited value to the diving community, but may be valuable as fish habitat. Polluted areas and areas affected by treated sewage effluent should be avoided to minimize resource exposure and possible human health risk.

In site planning, information and assistance can be obtained from federal, state, and local resource management, environmental quality, and scientific research agencies (see Sources of Information section). If sufficient background information does not exist to permit an adequate water quality assessment, prospective reef builders should ensure that this information is obtained through whatever means necessary, especially if some questions exist as to the suitability of a site based on water quality factors.

Biological Considerations

Artificial reef effectiveness is largely determined by the biological processes that enhance habitat for associated invertebrate and fish species or the ability of the reef to improve

recreational or commercial fishing. Specific biological criteria for reef siting are not appropriate in a national plan due to variations that exist in the biological requirements of reef communities in different geographical areas. This discussion, therefore, focuses on general procedure that should be used in isolating and accommodating key biological siting factors.

State and federal fishery management agencies, and other knowledgeable parties have the capability to determine the nature of fishery resources and fishing activities in the geographical areas targeted for reef construction. Objectives of the proposed reef should be compatible with fisheries conservation and management programs of the pertinent fishery management entities. Clear objectives for the proposed reef should be based on an assessment of public need and existing shore-based infrastructure. In addition, reef builders should select the target species, species groups, or life stages that they wish to enhance or rebuild. Critical habitat and environmental requirements of those species also must be identified. If selected target species are particularly sensitive to water temperature, salinity, dissolved oxygen levels, water turbidity, and contaminants, or if they have stringent habitat or food requirements, these parameters should be used as artificial reef site selection and design criteria. For example, in building reefs for snapper, grouper, black sea bass, rockfish, and other marine demersal species, low and medium profile reefs should be constructed from different sized materials which will create numerous holes and crevices of varying sizes, providing shelter for juveniles and adults.

Prospective reef builders should be aware of existing and proposed fishery management plans and regulations for the species that may be significantly affected. They should site or construct artificial reefs that would complement fishery management goals.

Artificial Reef Materials

Criteria

When planning artificial reef development, certain general characteristics can be useful in evaluating specific materials and design regardless of the specific purpose or location (marine or estuarine). Listed below are four major criteria that should be considered in evaluating the use of any artificial reef materials. These criteria, together with siting and management considerations, will in great part determine the success or failure of an artificial reef project. Safety is an additional major consideration during planning, transportation, construction, and operational phases of artificial reef projects. Reef builders are now fortunate to have the experience of nearly 40 years of state-sponsored artificial reef development to draw upon. Much of the experience gained by reef programs across the country has been documented in various ways. The Gulf States Marine Fisheries Commission recently developed a manual entitled "Guidelines for Artificial Reef Materials," for this purpose. The manual provides an in-depth analysis of reef materials based on the experiences of reef programs throughout the country. This document has been widely endorsed by researchers, fisheries managers and reef developers as an essential guide for marine artificial reef development. The Atlantic States Marine Fisheries Commission also has adopted the manual for application to its interstate artificial reef coordination activities along the Atlantic coast. In reviewing activities which

affect essential fish habitat in the Mid-Atlantic region of the EEZ, the Mid-Atlantic Fishery Management Council recently adopted a policy deferring to this document for review of artificial reef permit applications in waters under their jurisdiction. Due to the wide acceptance of this document, and the intent and ability of state reef developers to update the document as new information becomes available, this document should be used as the main source of information relative to specific materials proposed for construction of marine artificial reefs.

Function

Selection of materials which are known to be effective in stimulating desired growth of organisms and providing habitat for the target species is critically important in developing artificial reefs. Proper design or configuration of selected materials on the reef site will contribute significantly to artificial reef function. Surface area, profile, shape, orientation, open (interstitial) spaces, rugosity and size are major design features that affect the function of artificial reefs.

Compatibility

To maximize fishing and fisheries benefits, artificial reef materials and selected designs should minimize environmental risks and user conflicts. While some risks and tradeoffs are inevitable, knowledge of a site's physical and biological characteristics and the possible uses of a reef can help planners design reefs that will avoid major problems. For example, reefs designed for divers should have materials that are attractive and minimize safety risks. Artificial reefs placed near natural reefs can be designed to ensure the materials will not encroach on the natural reef.

Stability

The movement of reef materials off reef sites not only violates permit requirements, but can threaten navigation, foul commercial fishing grounds and litter beaches. This situation can be a significant threat to continued public support of artificial reef programs. All materials used in reef construction should be of proven stable design. In addition, the individual materials in composite structures must be stable on their own, since structures may break apart over time. For example, the bond between concrete and steel in a certain structure may break, but it is unlikely that either material will be moved individually.

Durability

Limited options are available for maintenance of underwater facilities like artificial reefs. Anything beyond the most rudimentary maintenance of a large-scale ocean reef is impractical and limited by expense. Artificial reef materials, therefore, must be resistant to deterioration and breakup. Durable materials will retain the desired structure and configuration, have low maintenance costs, and have long life expectancy in the marine environment.

Types of Materials

Artificial reefs have been built from a wide variety of materials over the years. The majority of artificial reef development activities in the US over the past fifty years have employed construction materials that were previously used or intended for other purposes. Some of these previously used materials have been more suitable for constructing artificial reefs than others have been. Many artificial reef programs have become dependent on such scrap materials due to their low cost and ready availability. However, it has become evident that a total reliance upon scrap materials may hinder the ability to reach reef development goals and objectives.

Many artificial reef programs employed a number of specifically engineered reef habitat structures. Such structures have become a more viable option for future artificial reef development projects, and may decrease the total dependency of reef development on the availability of scrap materials, and improve the overall effectiveness and safety of man-made reefs. The use of engineered materials has evolved with improved financial support, and willingness within private industry to develop new and affordable designed reef materials. This situation makes use of such material much more feasible than it was in previous years.

Regardless of the nature of materials utilized to construct artificial reefs, individual state agencies should be able to establish the particular materials that are deemed acceptable for use as reef structures in their coastal and adjacent offshore waters. The decision to allow or disallow the use of particular materials should be based on state and federal regulations and other guidelines, as well as the policies and procedures established by a particular state. Materials should only be considered for use if they possess characteristics which allow them to safely meet the established goals and objectives for the artificial reef project under consideration, and present no risk to the environment in which they are being placed. The "Guidelines for Marine Artificial Reef Materials" provides detailed information based on the experiences, benefits, and drawbacks of past uses of a variety of materials by state resource management agencies.

Secondary Use and Natural Materials

Due to their unpredictable availability, most scrap materials used in reef construction can be classified as "secondary use" materials, also known as "materials of opportunity." Effective artificial reefs have been constructed from secondary use and natural materials. A combination of various materials may provide for the greatest diversity in terms of both biological communities and users. The challenge is to implement state or regional site-specific reef plans and individual projects by balancing cost effectiveness with project effectiveness in achieving objectives. Planners must consider transportation, preparation, potential deployment, maintenance, and possible enhancement costs in assessing which materials meet reef development goals. Many existing, *de facto* artificial reefs such as shipwrecks, and gas and oil structures may already be appropriately sited. In such cases, they may only need to be located, enhanced, and publicized. Other excellent materials may already be at or near suitable development sites. Besides donation or sale of materials, a corporate sponsor, donor, or provider of materials may be willing to assist in transportation, preparation, and

deployment needs, especially if confronted with an expensive disposal alternative for these materials.

Although past artificial reef development in most states has been directly tied to the availability of these materials due to budgetary constraints, this may not be the most desirable situation for continued planning and development of reef construction efforts in the future. While a total dependency on scrap materials is not the most effective means of managing reef development activities, some forms of scrap, when available in the proper condition, are very desirable as reef construction materials and should continue to be utilized.

In some instances, natural materials such as quarry rock, limestone, or even shell have been utilized to construct artificial reefs. While these are not by definition scrap materials, their availability is sometimes dictated by a desire to move them from an existing site where for some reason they may no longer be desired. In these cases, they could be classified as secondary use materials. In other cases, as in the intent to build a reef to provide a rocky bottom substrate, material such as quarry rock is obviously the most suitable material available to create the intended habitat.

Individual state artificial reef programs or resource management agencies, or other approved reef programs, should always serve as the central contact and coordination point for evaluating, approving, distributing, and deploying materials of opportunity on a given state's system of artificial reefs. Before agreeing to approve any materials for use in reef construction, the managing or oversight agency should carefully inspect the materials and ensure that they are environmentally safe, structurally and physically stable, needed, practical, and can be deployed in a cost-effective and safe manner. A thorough inspection of potentially suitable materials should be conducted as early in the proposed reef construction effort as possible to minimize wasting time or effort on suitable materials.

A detailed discussion of the benefits, limitations and problems encountered in using the almost limitless list of materials of opportunity that have been employed over the years in the construction of artificial reefs is well beyond the scope of this document. The collective experience of the state artificial reef managers over the past several decades has revealed that a number of secondary use materials are unsuitable as artificial reef material. Among those that have been found to be persistently problematic are: wood, fiberglass, plastic, light vehicle bodies, fiberglass boats and boat molds, railroad cars, and light gauge metal items, such as refrigerators, washing machines, and clothes dryers. These materials should not be used in artificial reef development, unless specific design features can be employed to provide durability and stability. For instance, plastics and fiberglass are durable and can be designed with sufficient density to ensure stability. Vehicle tires also are problematic. However, there have been limited cases where they have been used without documented negative impact. In particular, tires have been imbedded in concrete that both encases the tires and provides enough ballast to ensure stability. The Plan recommends that tires should be used as artificial reef materials only with great caution. In addition to the "Guidelines for Marine Artificial Reef Material," documentation of the use of materials has been, and will continue to be, compiled through the experiences of artificial reef program managers, and should be

consulted prior to consideration of using any secondary use material in a reef development project.

Manufactured Reef Structures

A total reliance on the availability of suitable secondary use materials for development of a productive system of artificial reefs presents several problems. If an artificial reef program is to function in a manner that is conducive to effective long-term planning and the pursuit of realistic reef development goals and objectives, it cannot continue to base reef construction solely on the unpredictable availability and diminished quantity of acceptable scrap materials. The only practical solution is to consider the incorporation of manufactured reef structures into planned reef development activities.

Manufactured artificial reef structures can be developed which possess the characteristics desired of a reef substrate for a specific environment, application, or end result. Although the initial costs in procuring these reef materials may be higher than those involved in obtaining many scrap materials, the transportation, handling and deployment costs are typically about the same. Also, the lack of expense in having to clean or otherwise prepare these structures can often balance out this difference completely. Specific qualities of stability, durability, structural integrity, transportability, and biological effectiveness can be engineered into a reef material design, which gives manufactured reef structures a great advantage over most scrap materials which are severely limited in how they can be modified or deployed.

Manufactured reef units can be deployed in any quantity, profile, and pattern required, allowing them to provide for maximum efficiency of the materials used in achieving the desired results. Materials of opportunity such as ships must be deployed in a single unit, often with a great deal of the total material volume being taken up in vertical profile. The same volume of designed reef materials that would be found in a vessel can be spread over a much larger area of ocean bottom, allowing for better access to a larger number of reef users.

One of the most significant advantages offered by the use of designed reef structures is the ability to procure them in any quantity as needed. This allows reef managers to plan ahead, make the best use of available funding, and predict costs required for accomplishing specific reef construction objectives. When depending on secondary use materials for reef development, this type of short and long-term planning is rarely possible.

Transfer of Construction Materials

Donation of materials for reef construction represents an opportunity for both the donor and the program receiving the materials. Such donations have allowed development of many artificial reefs that otherwise would not have been possible. In most cases, the costs to the donor for providing the reef material have been offset by reduced removal or disposal costs, treatment of the transfer as a charitable donation (to government agencies), and favorable publicity.

Incentives

Potential donors of reef material often face large salvage or disposal costs for retired or surplus materials. These materials could serve as effective reef materials, but additional costs to relocate them on an artificial reef site may be much higher than normal disposal costs. Innovative thinking is needed to identify possible incentives for donors that would allow reef builders to obtain donated reef material that, if fabricated from raw materials, would be very expensive to construct and deploy. This donated reef material, once on site, could increase recreational and commercial fishing opportunities and contribute to coastal economies for many years.

Some form of incentive could be considered which would encourage future donations of secondary use materials where there would be a cost to the donor, beyond normal disposal costs. One such incentive could be modified tax obligations.

Alternatives

The value of donated materials can be used for matching fund requirements in financial assistance where appropriate (Federal Aid in Sport Fish Restoration Act) administered by the reef program. This can serve to facilitate transfer of materials to the reef builder and for reef development.

Reef Design

The concept of "designing" artificial reef systems as well as individual reefs, or even specific reef structures, is one that has been widely used in Japan for a number of years. It has been demonstrated that proper design techniques can greatly affect many factors such as costs, biological effectiveness, long-term cost effectiveness, and general performance of the reef or reef system. The "design" of most artificial reefs in the US traditionally has been left to chance as a result of using the most readily available and cost effective materials. However, attempts have been made to construct reefs in such a way that their resulting overall design takes into consideration many of the factors required to achieve the most effective and efficient reef possible with the materials at hand.

Criteria

In an effort to improve the manner in which artificial reefs are built, many states are now taking into consideration a number of key design criteria. These criteria are employed in developing reefs that will produce the maximum amount of benefit possible for the biological reef community itself, as well as the users of the reef. To as great a degree as possible, artificial reefs should be constructed so that the overall design of the reef, as well as individual reef structures, are tailored specifically to allow the best chance of achieving the intended purpose of the reef.

In furthering the development of effective marine artificial reefs in the US, artificial reef planners and developers should make every attempt to incorporate the reef design criteria listed below into all man-made reef construction activities.

Practicality
The overall design of the reef, as well as individual reef materials used should be chosen with an achievable goal in mind. Reef structures utilized must be easy to acquire or manufacture, and their handling, transportation, preparation, and placement on the reef must be realistically accomplished within safe and relatively low-risk, cost-effective limits.

Effectiveness in achieving reef objective
The reef layout and materials used should be designed to provide the users of the reef the best possible chances of receiving the desired benefits of the reef. Reefs intended for a specific purpose (e.g. trolling, bottom-fishing, SCUBA diving, nursery grounds, etc.) should be constructed with this in mind. Certain materials used in reef construction are more suited for one particular use while others are better for general or multiple uses.

Reef configuration
The overall configuration of the materials on a reef will play an important role in determining how the reef works as well as how effectively it can be utilized. Placement of different types of structures on separate parts of the reef will provide increased diversity of reef fish assemblages, and also allow multiple uses of the reef site. Divers and fishermen can be separated in this manner, as can troll fishermen and fishermen wishing to anchor over the structure.

Reef profile
The vertical profile of a reef structure may be important in determining the overall fish species composition and biomass of a given reef. Low profile reefs are thought to be most successful in providing a suitable habitat for more demersal species, while high profile reefs appear to work better for many pelagic fishes. A combination of high and low profile construction materials can often be utilized within one permitted location to create a reef targeting a potentially more diverse fish assemblage.

Interstitial space
The quantity and nature of interstitial spaces in reef structures are important in determining the degree and complexity of the biological community developing on and around the reef. Numerous holes, crevices, walls and overhangs in a reef structure allow for a much more diverse community in general than that which would develop on a reef material with less structural complexity. Adequate interstitial spaces are necessary to establish a rich diversity of motile invertebrates as well as numerous cryptic fish species.

Total surface area
In most cases, the total biomass that can be supported on an artificial reef will be directly related to the quantity and quality of effective surface area available. This is particularly true of low profile benthic reefs in which the fouling community of sessile marine organisms achieved on the reef may be important to the subsequent development of the demersal fish community established on and around the reef materials. Many sessile and motile invertebrates are important food items for many of the fish species inhabiting the reefs. The

greater the surface area available to these organisms, the more significant the food source available to other levels of the reef community.

Openness of reef materials

Reef materials should be selected which offer suitable openness to allow adequate water circulation through as much of the reef as possible. This should prevent the stagnation of water in some parts of the reef, which could result in minimized effectiveness of the overall reef. Openness of the reef also allows for better utilization of all surfaces of structures for the establishment of sessile invertebrates, as well as the potential for improved access to fish and motile invertebrates that may be more cryptic in nature.

REGULATORY REQUIREMENTS

Corps of Engineers

The Corps, in accordance with Section 10 of the RHA of 1899 and Section 404 of the CWA, is responsible for regulating all construction activities which take place in the waters of the US. All legal artificial reef construction activities require the issuance of a Corps permit. Prior to approval of such a permit, other concerned agencies and departments within the Federal Government, as well as state agencies and other groups, are given the opportunity to review the proposed work to ensure compliance with existing regulations. This review also helps prevent the approval of projects that might negatively impact other existing or planned activities, or which actually may be an ocean dumping project.

Artificial reef construction permits are issued in accordance with Corps guidelines established in 33 CFR (Parts 320 through 330) of November 1986. The DOI, DOC, DOT, DOD, and EPA all have a vested interest in the proper development and maintenance of artificial reefs to varying degrees. Each is allowed to comment on the issuance of any proposed reef permit by the Corps.

Artificial reef planners, developers, and managers should work closely with the Corps Regulatory Branch personnel in the district in which they intend to maintain artificial reefs. Good communication and close cooperation with these individuals, as well as clear understanding of pertinent regulations and local Corps district policies and procedures pertaining to the issuance of artificial reef construction permits is vital to a successful reef program.

Although in some cases, private entities hold permits for artificial reef sites, eligibility to hold an artificial reef permit should be restricted to the state agency responsible for managing marine fisheries resources. Under all circumstances, the Corps will contact the appropriate state fishery agency prior to issuance of an artificial reef permit to give the state first option for holding permits on a proposed artificial reef site. At a minimum, permit applications must be reviewed by the state fishery management agency prior to issuance of a permit to construct an artificial reef. These agencies hold the public trusts in management of the associated

resources and are responsible for long-term accountability of liability on state-permitted sites. Coordination of reef development in states without a state wide, site specific plan requires state marine fishery resource agencies to work closely with the district Corps office to assure artificial reef permits are consistent with fishery management objectives. Restriction of artificial reef permits to state fishery management agencies should be established in the Corps regulatory programs at national and district offices. The NMFS and NOS also should provide guidance to assist the Corps in such regulatory action as may be required.

Coast Guard

Often, it is desirable or necessary to mark artificial reefs with buoys (aids to navigation). The USCG manages the private aids to navigation program to ensure that aids being maintained conform to certain minimum standards, and to promote the accuracy of information available to mariners. In some cases, aids are required because the artificial reef poses some hazard to navigation. These costs can be substantial. If, for example, an offshore oil or gas structure, which normally must be removed, was left standing as artificial reef material and as a convenient "landmark" for users of the artificial reef site, it would be a hazard to navigation and need a continuously maintained navigation aid. In other cases, the responsible party may prefer to have a navigation aid for the convenience of those who use the reef even though it is not required. In either case, it is necessary to submit an application to the commander of the USCG district having jurisdiction.

Some districts have prepared written descriptions of factors they consider critical in evaluating a private aid application for an artificial reef. Reference to these criteria should help reef builders select specific aids for the reef. Prospective reef builders may be able to contract with a local company to install and maintain aids at the site; however, the permittee is responsible for the aid.

As part of the planning process for an artificial reef, the sponsor should be aware that a significant cost may be involved in buying and maintaining the appropriate aids to navigation. Also, reef management should include a mechanism by which the aid is monitored for compliance with the USCG authorization for color and signal characteristics and to ensure that the aid stays on station.

When an artificial reef is not considered to be an obstruction to navigation, aids established only for the purpose of indicating the presence of a reef to users may be discontinued when construction is completed, if authorized by the USCG District Commander. The USCG District Commander upon receiving an application from the reef sponsor will make the decision on when navigation aid is no longer mandatory. Generally, site specific considerations determine requirements. Therefore, a simple, universal formula for a program as complex and technical as aids to navigation has been difficult to achieve.

Environmental Protection Agency

The Environmental Protection Agency (EPA) is required to consult with the Corps to assure that any permit they issue under section 402 of the CWA is consistent with the permit for a particular artificial reef issued by the Corps. Under section 404 of the CWA, the EPA may prohibit, restrict, or withdraw use of a site for the discharge of dredged or fill material which would have unacceptable effects on fish, wildlife, shellfish, recreation, or municipal water supplies.

States and Local Governments

Coastal states have the authority to regulate artificial reef development activities and the disposal of solid materials into coastal waters under their jurisdictions. Many states have adopted artificial reef plans which contain guidelines and regulatory provisions to control artificial reef development activities.

It is strongly recommended that states, if they have not already done so, establish penalties for illegal disposal of solid materials in coastal waters, and for violating artificial reef regulations. Such penalties should be substantial enough to deter those illegal activities, and should at least be compatible with penalties established for similar violations in federal waters.

In some cases, a survey to locate possible archeological sites may be required by a state before approval of a permit to develop an artificial reef. Other state and/or local permits may be required. Many Corps districts have working agreements with state agencies for joint application and/or processing of permits. Where available, this arrangement will streamline the overall permitting process.

Construction

Although the importance of material composition and design is understood, successful artificial reef construction is ultimately determined by the ability of managers to predict and plan on-site deployment of materials. This process should begin well before field operations with pre-site surveys, decisions on material options, deployment techniques, design choices, and permitting. Throughout the planning process, managers and permitting agencies should assess the possible effects of major storms, especially the effect on material stability and structural integrity.

Another important pre-placement consideration is the selection of an accessible material staging site that will allow safe and efficient construction, storing, and loading of materials. Equipment and personnel needed to handle the materials must be readily available at the site to (1) allow construction of the reef during favorable weather conditions; (2) coordinate with donated or contracted services such as towing and other volunteer or contracted assistance; and (3) reduce unnecessary delays.

Preplanning among involved agencies not only clarifies mission objectives, but also ensures that all participants are aware of planned reef material configurations and orientations. Careful attention to planning details can assure the final success of the project. For example, reef planners should:

1) acquire an adequate environmental and biological data base,

2) select safe weather and water conditions appropriate to the type of transportation and construction technique,

3) employ reputable and competent personnel,

4) coordinate with any biologists, oceanographers, or engineers studying the reef,

5) coordinate with USCG or local marine police,

6) assure that all equipment is tested, sufficient for the task to be performed,

7) obtain liability insurance, if needed, to protect all involved (see Liability section),

8) assure that all pre-surveyed sites can be successfully relocated and are clearly marked by project coordinators prior to arrival of materials,

9) maintain staging area to be compatible with surrounding neighborhood and to avoid potential conflicts at the staging area,

10) stage and deploy primary or emergency navigational aids, as required,

11) manage the flow of raw materials to the staging area and the movement of completed units to the reef site,

12) assess daylight and other operational constraints,

13) supervise any required clean-up after placing reef materials on the site (e.g., overlooked floatables),

14) be prepared to cancel operations if necessary to ensure the safety of participants and the proper placement of materials, and

15) secure funding and other support to complete construction.

Management

General

Artificial reefs can be used as an effective management tool for fishery resources. To be most effective, they must be developed using clear, specific, realistic, and measurable objectives. With specific objectives in mind, reef developers/managers can choose and plan strategies and reef characteristics that will best meet their goals. Reef management should begin with the objective(s) for a reef and continue for the life of that reef. When a man-made reef has been constructed, another important phase of reef management begins: monitoring and maintenance.

Specific management strategies will depend on the objective(s) of the reef and compliance with existing regulations or resource management programs. Generally, in marine waters beyond the territorial limit, the FMCs determine management strategies for resources or users through specific FMPs. Coastal fishery resources that migrate between state, and often federal, jurisdictions also may be regulated through interstate FMPs developed and implemented by the respective IFMC. Therefore, FMCs and IMFCs should be consulted from the inception in artificial reef development. These entities also have requirements in their FMPs to designate certain habitat as essential to the management of the species covered under a specific FMP. These entities are a major source of information about the fisheries resources and can help identify areas of potential conflicts or areas of concern in federal waters, and can identify issues of compatibility of a proposed reef project with management objectives for the effected fisheries.

Special Management Zone (SMZ) designation is one alternative for maintaining compatibility of reef development with fisheries management objectives. The FMPs for groupers and snappers in the Gulf of Mexico and the South Atlantic, as well the Atlantic black seabass FMP contain SMZ language specific to artificial reef development and use in these fisheries. The State of New York also has implemented new reef-use rules that include SMZ-type authority over natural and artificial reefs and wrecks. Man-made reefs designated as SMZs offer reef mangers much more flexibility to effectively utilize reefs as fishery management tools by providing a degree of regulatory control which otherwise would not exist. Reefs can be planned, designed and developed with specific management objectives in mind (e.g. stock enhancement of a group of fish species in a particular environment) and be supported by the regulatory language for an SMZ. SMZs or similar regulatory measures allow artificial reefs to be used as non-traditional fishery management tools.

States should be the primary source of management advice pertaining to artificial reefs in their coastal waters. Since publication of the 1985 Plan, about half of the coastal states in the US have developed state-specific marine artificial reef plans. States with artificial reef programs are encouraged to update their plans periodically, and those without plans should develop site-specific artificial reef plans for areas within their jurisdiction and in adjacent waters. These site-specific plans facilitate development and management of artificial reefs in a responsible manner, based on user needs and the best technical or scientific information

available on local conditions. Such plans also can deter haphazard development by non-state entities. Private reef construction, if allowed, should be conducted under the auspices of the states, as it is the permit holder's responsibility to comply with applicable laws, regulations, and permit conditions. Measurable performance standards are essential for mangers to evaluate accurately the effects of reefs. To assist in evaluating reef success, standards should be a part of the site-specific plan and these standards should require the builder, sponsor, scientific advisor, or management entity to demonstrate that reef objectives are met. These standards could include a measure of the following:

1) increase in any number or combination of resource variables (number of fish per unit area or biomass per unit area),

2) increases in harvest (catch per unit of effort) or an increase in the average size of fish caught,

3) increases in the number of fishermen using an area, or

4) reduction in user conflicts or changes in other socio-economic factors affecting the specific purpose of the artificial reef.

Information gathered from monitoring can be used to test predictions made in the planning phase about the designs, materials, or total structure of an artificial reef. The results of these tests can be used to:

1) improve or refine siting or design,

2) evaluate benefits/costs,

3) effect regulations to protect stocks from overharvesting or to resolve user conflict, and

4) propose alternative management strategies or options.

Management should provide:

1) public or administrative awareness about the effectiveness of the artificial reef programs,

2) assurance of adequate long-term funding for the program,

3) encouragement of research on artificial reefs, and

4) documentation of reef development and effects.

Availability of information to reef users relative to the reef site is critical to achieving benefits from the reef project. Whenever possible, artificial reef builders should develop and distribute public information brochures and/or flyers describing:

1) reef locations,

2) fishing conditions at each site,

3) applicable fishing regulations or site restrictions (e.g., observance of diving flags, anchoring guidelines, fishing gear restrictions, and catch limitations), and

4) tips on courtesies that should be extended to other reef users.

Reef design and the effective use of buoys can be important parts of artificial reef management. Reefs with numerous clumps of material can provide more anglers with better fishing and fewer conflicts than a single clump reef. Buoys can be used to place anglers over productive fishing areas of the reef. The State of Washington has constructed reef structures in different areas within the permitted reef site to direct fishing effort by buoy placement. The state places some reef site structure away from the reef buoy(s) to minimize the chance of anglers locating the material. This creates small sanctuaries, or less heavily fished areas which could be buoyed later if overharvest occurs on the areas buoyed initially.

Monitoring

There are two primary reasons for establishing monitoring programs as part of reef management. The first is to assure compliance with the conditions defined in any authorizing permits or other applicable laws or regulations (see Act, section 205 b). The second is to provide an assessment of the predicted performance of reefs and assure that the reefs meet the general standards established in section 203 of the Act.

The specific monitoring strategies will depend on the degree of compliance required and the objectives and resources of the reef builder. The information obtained should be useful for improving existing reefs and for building effective reefs in the future.

Compliance Monitoring

Specific compliance monitoring requirements will be determined by governing law, regulations, and conditions for approval of the various required permits (e.g., USCG permits, Corps permits, state permits, and conditions of consistency concurrence for Coastal Zone Management purposes). The degree to which federal, state, or local agencies will carry out compliance inspections of an artificial reef also will be governed by applicable law, regulations, and the conditions of approval for the permit(s) under which the artificial reef is authorized. Generally, recording and reporting requirements should be held to a minimum to demonstrate that conditions of the governing permits are being met.

Compliance monitoring should involve the documentation of material stability and structural integrity throughout the life of the reef, and may be conducted through the use of simple bathymetric surveying instrumentation such as hull mounted depth recorders. When available, more sophisticated gear such as side-scan sonars or magnetometers may be useful in mapping out the positions of man-made reef materials when deployed over a large area. Accurate and repeatable navigational data establishing reef material positions are essential. Compliance monitoring surveys often may require the use of visual confirmation of reef material obtained through observations provided by SCUBA divers. Cable-controlled cameras, as well as remotely operated vehicles with cameras, also may be used when practical or available, especially when water depth or sea conditions preclude the use of divers.

Performance Monitoring

Generally, performance monitoring is voluntary; it is not required under the authorizing permit(s). Performance monitoring involves the on-going evaluation of an artificial reef to determine whether or not the reef is accomplishing the purpose(s) for which it was established. This type of monitoring also can detect whether the reef is having any unexpected negative consequences, as well as provide a great deal of insight into the need for future modifications to construction techniques, identifying research priorities and documenting the need for alternative management strategies or new regulations. Performance monitoring assesses the physical, biological and socio-economic factors essential in documenting the degree of success as well as all impacts of a given artificial reef or reef system.

Engineering Assessment

The long-term success of all artificial reefs ultimately is dependent upon the reef materials remaining in place and continuing to provide a durable, safe and effective substrate for the foundation of the reef community itself. Continued performance monitoring of artificial reefs over the years provides a mechanism by which to evaluate and learn from the efforts of both past and present reef construction activities, thus allowing for improvements in future reef development techniques.

Reef material stability and structural integrity are critical factors involved in evaluating the success of a particular type of reef material from an engineering standpoint. Remote sensing can be used for compliance monitoring of reef structure movement. However, the most reliable and generally easiest method of evaluating the condition of artificial reef structures is by conducting close examination with divers or remotely controlled cameras.

The information gained through the *in situ* engineering evaluation of artificial reef materials should be adequately documented and carefully employed in the consideration of future reef design and construction. Certain materials will be better suited for applications in specific reef environments (offshore versus nearshore versus estuarine) and some will be found which do not meet acceptable standards for continued use under almost any conditions. Artificial reef programs should ensure that they have an adequate body of knowledge and sufficient memory to learn from past failures as well as successes. This is one of the most important reasons for the establishment of an active reef monitoring effort.

Biological Assessment

Most marine artificial reefs are constructed for the purpose of effecting positive change in the local ecology of a given area of ocean bottom. With this in mind, a detailed biological assessment of the impact of the reefs should be conducted to evaluate success of the reef in accomplishing its objective(s), or to detect any possible negative effects. In most cases, this can be done through underwater observations and other data collected during routine reef monitoring activities. This type of monitoring can provide a great deal of information regarding the degree of development of the reef community, and indicate the success of the reef in producing both short-term and long-term results in enhancing desired finfish populations. Additional quantifiable data also may be collected regarding many other important ecological aspects of an artificial reef, and include the following:

1) an accounting of development of sessile invertebrate communities on different types of structures,

2) importance and degree of interaction between fish communities and invertebrate communities associated with the reefs, and

3) association of key target fish species with certain reef designs or locations and long-term changes, which may take place in reef community structures as reefs age.

One obvious advantage of this type of monitoring program is the ability to detect and quickly document potential negative consequences from reef construction or utilization practices. This would therefore allow for the opportunity to respond in a timely manner in these situations and modify existing policies, practices or regulations if necessary. Biological monitoring of existing reefs is also critical in identifying research priorities in regards to gaining a better understanding of how artificial reefs work and how they can be best used to meet fisheries management objectives.

Fisheries Assessment

While marine artificial reefs can be created for a number of purposes, the most commonly encountered use of reefs is for the enhancement of a variety of fishing activities. Any reliable measurement of the success of a given reef or system of reefs would therefore involve the evaluation of quantifiable impacts of the reef on some type of fishery. It is recommended that routine collection of data such as species commonly caught, catch per unit of effort, total catch, effectiveness of individual gear types or fishing methods, use patterns, and seasonal harvest rates be maintained throughout the effective life span of a reef. This information provides a baseline for evaluation of the effectiveness of the reef.

Performance monitoring activities directed towards obtaining information such as this will greatly assist reef managers in determining potential impacts on individual fish populations as well as the effects of individual fishing practices or gear types. Information obtained will be essential in allowing fisheries resource managers to make logical decisions regarding the need for new regulations, changes in fishing practices, specific needs in public education, and the need for additional detailed data, obtainable through directed research activities.

Socio-economic Assessment

The impact of the reef(s) on a variety of social and economic factors within a given region of interest (state, county, municipal, etc.) is a key element in measuring the overall success of any artificial reef or system of reefs, and provides a basic measurement in cost/benefit analyses. Monitoring should be conducted on a relatively frequent basis to accurately document any measurable benefits that could be used to determine the overall cost-effectiveness of reef development, construction and maintenance efforts. Such factors as direct and indirect economic benefits, improved quality of fishing, increased fishing safety, decreased fuel consumption per trip, lessened or increased user conflicts, changes in fishing patterns or techniques, as well as others, should be routinely examined to determine the overall impact of the reefs.

Maintenance

Maintenance also should be part of a reef program. Certain maintenance may be necessary to comply with permit conditions (buoys, materials scattering, etc.). Additional maintenance, though not required by law, can enhance reef effectiveness (e.g., removing entangled fishing gear, repositioning buoys, and adding materials.).

Maintenance to Comply with Permit Requirements

The buoy system, when utilized, must be maintained to comply with USCG permit requirements. This may involve painting, repair, or complete replacement of badly deteriorated buoys or mooring systems. If monitoring reveals that a buoy does not mark the actual location of the reef, either because it was deployed inaccurately, or because the materials or the buoy have moved, the buoy may need to be repositioned or the permit modified.

Maintaining Reef Effectiveness

If monitoring reveals that the reef materials were inappropriate for the substrate, resulting in sunken or covered material, then maintenance might include deploying additional materials more suited to the site conditions. This maintenance also may be the answer to more complex biological problems, such as failure to attract the target species. Additional higher or lower profile material might provide the missing habitat.

Maintaining Documentation

Accurate documentation of a reef's developmental stages, especially the addition of materials, is important for determining reef effectiveness and long-term costs. Documentation should include the types of reef materials, deployment dates, locations of various materials on the reef, and fish species present. Whenever possible, information should be recorded on fisherman and diver use of the artificial reef.

Liability

Improper artificial reef placement can potentially injure persons, property, and natural resources. Risks include:

1) injuries to personnel handling the reef materials,

2) damage to vessels transporting reef materials,

3) improper location causing damage to fishing gear,

4) damage to vessels in transit over the reef,

5) damage to buried pipelines and cable,

6) injury to recreational divers,

7) decomposition or movement of the reef material to an unauthorized location,

8) environmental hazards caused by incomplete cleaning of hulls or holds containing toxic residues, or

9) damages to existing natural resources such as crushing live coral reefs.

The Act of 1984, (Act) Title II of PL 98-623, section 205 c, addresses the liability issue from three perspectives: 1) that of the reef permittee, 2) that of the materials donor, and 3) that of the Federal Government. Issues of liability that are not addressed by the legislation will require reference to maritime law, sovereign immunity, and traditional tort concepts.

Described below is an hypothetical situation that culminates in the actual placement of reef materials in navigable waters of the US on the Continental Shelf. There are several stages in this process.

Plan and Permit Stage

The Act requires the Secretary of Commerce to publish a long-term plan that will establish criteria for design, construction, and siting of artificial reefs. This Plan and the statutory standards of section 203 of the Act guide the Corps in its decision to issue the permit required to begin construction. The materials to be used for the reef must minimize environmental risks, and the placement of the reef must not create an unreasonable hazard to navigation.

The Act creates no liability on the part of the US. The Suits in Admiralty Act is the basic remedy for injuries or damage resulting from maritime actions of the Federal Government. Under this statue, if the Corps negligently authorized placement of a reef on top of a pipeline or undersea cable or in shallower water than intended, the US might be sued for any damages

that resulted from that negligence. Some courts, however, have implied an exemption form liability under the Suits in Admiralty Act for discretionary functions of the Federal Government. In this respect federal sovereign immunity has not been waived. As a result, an intentional Federal Government decision to permit a reef in a particular place, or to require certain materials for construction, would not create liability even if there were some risks involved, assuming that the explicit requirements of the Act had been satisfied.

Construction Stage

When a permit has been obtained, the materials must be transported to the reef site and properly located, anchored, and marked. The Act does not address the transportation phase. Presumably maritime accidents or injury to crew, grounding, premature discharge, collision, and/or sinking could occur. Liability for transportation accidents would be the same as in any other maritime context.

The Act provides that, once title has transferred, the donor of the materials to be used in reef construction is immune from liability if the materials meet the requirements of the Plan and are not otherwise defective. It would therefore be in any donor's interest to verify that the materials meet the Plan requirement and to document title transfer.

The actual placement of materials in the water will usually involve private parties, either volunteers to, or contractors of, the permit holder. Since the permit will specify the location and procedures for placing and marking, the permit holder would generally be liable for any failure to follow those specifications [(Act, section 205(c)(2)]. Conversely, strict adherence to these requirements of the permit will immunize the permit holder from liability for injuries resulting from those required activities [(Act, section 205(c)(1)].

Monitoring Stage

When a reef has been properly located, marked on navigation charts if necessary, and any required surface markers affixed, there should be very little potential for liability. Unless the reef breaks up or moves to a different location, or the marker buoys become detached, sink, or are otherwise destroyed, it would be each vessel owner's responsibility to avoid collision. The Plan suggests, and each permit may contain, requirements for systematic monitoring of each new artificial reef. To avoid liability, permit holders must follow these requirements.

Diving accidents may occur with use by recreational divers. In this respect, an artificial reef is like a public park. There are dangers in most parks, guardrails and fences cannot be placed everywhere, and everyone who visits the park assumes some risk of injury. A warning could be placed on nautical charts and posted in local dive shops to warn of these dangers. However, each case would probably involve determination of comparative negligence.

A state government may have sovereign immunity from liability. It is unclear whether the Act affects any state claim of sovereign immunity.

General Observations

Placement of a man-made reef, particularly if sponsored by a public agency, involves decisions similar to those a municipality makes in building a public park. The requirement for a federal permit and the standards and procedures of the Act, provide additional assurances that the reef will be safely located. Strict adherence to all the terms of the permit immunize the permit holder for activities the Federal Government has specified in the permit. The Federal Government will generally not be liable for discretionary acts in specifying permit terms and conditions. The liability of the Federal Government under the Act is no different than other forms of government activity. The liability for transportation accidents is the same as for most other maritime activities. To minimize the risks for all concerned, the Secretary of Commerce and the Corps should monitor and update explicit permit standards and conditions as necessary. If these conditions are not negligently devised and are properly monitored, both the Federal Government and the permit holder will be protected from liability to the greatest possible degree.

EXISTING INFORMATION AND RESEARCH NEEDS

Sources of Information

In the last decade or two, the amount of information available on the design, construction, use, ecology, and effectiveness of artificial reefs has increased dramatically. Academic institutions, state and federal fishery management agencies, IMFCs, and in some cases, county or local groups, have studied or sponsored studies on multiple aspects of artificial reefs and their use as fishery management, habitat management, or ecological research tools. These studies have resulted in a rapidly expanding body of information which is available from a variety of sources, including electronic data bases, published papers, and reports. The now defunct Sport Fishing Institute compiled a comprehensive bibliography of sources relative to various aspects of artificial reef development and research in 1993. This document provides over 700 citations. Below are some primary sources of information about facets of artificial reef planning, construction, siting, resource management, and almost all other artificial reef related topics based on regional, national and worldwide research that might be considered for planning their use in waters of the US.

Most recent (since 1978) published results of studies involving artificial reefs or habitats can be located electronically (CD-ROM, Internet or bibliographic retrieval services such as Knight-Ridder's DIALOG) or by hard-copy, using appropriate key words or phrases within data bases such as Aquatic Sciences and Fisheries Abstracts (ASFA). Most academic or research libraries supporting biological studies subscribe to these services. Some of the most comprehensive individual sources of artificial reef information are the papers published as proceedings of six international artificial reef and habitat conferences (the last occurred in 1995), and from some other conferences or workshops. Several of these are provided below.

ECOSET '95. The sixth international conference on aquatic habitat enhancements; 2 vol. Proceedings. Japan Intern. Mar. Sci and Tech. Fed, Tokyo. 924 p. (Nine technical sessions included papers on diverse aspects of different types of artificial reefs and FADS - ecological structure and function of fish and other resources; use of recycled and waste materials; hydraulic, hydrodynamic and geologic factors; artificial habitats and habitat loss or degradation mitigation; micro- and macroalgal production; summaries of use and research from different parts of the world, and other related topics, with an emphasis on Asian studies.)

Fifth International Conference on Aquatic Habitat Enhancement, 3-7 November 1991, Long Beach California, USA. 1994. Bull. Mar. Sci. 55(2&3):1-1359. (Proceedings, one hundred eighty presentations covered special sessions on ash reefs, local programs, offshore structures, as well as general sessions.)

Recent Advances in Aquatic Habitat Technology - Nakamura, M., Grove, R. And Sonu, C (eds). 1991. Proceedings of Japan-U.S. Symposium on Artificial Habitats for Fisheries. Southern California Edison Co., Rosemead, CA. 345 p. (Thirty-three papers presented on advances in artificial reef technology.)

Seaman, W. Jr. And L.M. Sprague. 1991. Artificial habitats for marine and freshwater fisheries, 285 p., Academic Press. (Organizes and summaries the information presented in the fourth and third international conferences on artificial habitats or reefs, noted below.)

Fourth International Conference on Artificial Habitats for Fisheries, November 2-6, 1987, Miami, Florida. 1989. Bull. Mar. Sci. 44(2):527-1073. (Proceedings, seventy papers presented updates or results of new studies.)

D'Itri, F.M. (ed). 1985. Artificial Reefs, marine and freshwater applications. Lewis Publishers, Inc. Chelsea MI. 589 p. (Twenty-five papers cover physical and limnological, design and construction, ecological, and legal and regulatory aspects.)

Third International Artificial Reef Conference, 3-5 November 1983. Newport Beach, California. 1985. Bull. Mar. Sci. 37:1-402. (Proceedings, fifty-six papers or abstracts, including a comprehensive critical review of artificial reef research to that time by Bohnsack and Sutherland.)

The Biological Bases for Reef Fishery Management - Huntsman, G., Nicolson, W. and Fox, W. (Eds). 1980. NOAA Tech. Memo. NMFS-SEFC-80. (Proceedings of a workshop that covered aging, reproduction, recruitment, stock assessment, community structure, and modeling of reef fish populations.)

The former Sport Fishing Institute (Washington, DC) published a series of technical reports and planning guides from 1984 to 1994 related to artificial reef development. As products of their Artificial Reef Development Center, these reports covered such issues as permitting procedures, siting, exclusion mapping, maintenance, funding, liability concerns, transportation costs, economic analysis, reef use and management, and fishery conflicts. It also published

a newsletter, "Reef Briefs," that kept artificial reef managers informed of current affairs, and drafted a comprehensive bibliography; these are available from Atlantic States Marine Fisheries Commission (ASMFC, 1444 Eye St, NW, Sixth Floor, Washington, DC 20005).

Concurrently, ASMFC instituted an Artificial Reef Advisory Committee (ARAC). This active committee also produced an number of special reports on artificial reef topics, e.g., profiling artificial reef development by states (1988), research needs (1990), reef materials (1992), guidelines for planning and management (1993), use of vessels (1994), special management zones (1994), and federal aid (1996). The Gulf States Marine Fisheries Commission (GSMFC, P.O. Box 726, Ocean Springs, MS 39566) has a similar committee and also published similar guidance reports on use, monitoring and assessing artificial reef materials, and summaries (Profiles) of individual artificial reefs in the Gulf of Mexico.

Most coastal states, and some territories, such as Puerto Rico and Pacific Islands, have artificial reef programs. Many of these have or are developing their own state-wide artificial reef plans to define their objectives and guide their long-term construction and evaluation efforts, as recommended in the original 1985 version of the Plan. These state plans can be examined as sources of local or regional information on the need for and use of artificial reefs. Most are readily available from marine fisheries agencies in the specific state. Other artificial reef information, such as location of each artificial reef and the types of material used, also is available from these agencies. Although this Plan is not focused on freshwater artificial reef or habitat efforts, information on specific freshwater applications is also available from state fishery management agencies.

Most state artificial reef programs use Federal-Aid-in-Sport Fish Restoration funds to construct and monitor their artificial reefs. The National Sea Grant Program also supports some artificial reef studies. This funding usually requires progress or completion reports on the specific activities being funded. These reports can provide additional technical information on artificial reefs. The reports often cover angler use surveys, construction methods, design/materials assessment, and programmatic evaluations. Most of these reports are listed in the Federal Research in Progress and National Technical Information Service (NTIS) electronic information databases (within DIALOG), or can be requested from respective state agencies. NTIS listings are also available through FEDWORLD on the Internet. Sea Grant publications can be accessed via the Internet at http://nsgd.gso.uri.edu/; or by writing to the National Sea Grant Depository, Pell Library, University of Rhode Island, Narragansett, RI 02882-1197.

Although most academic research on artificial reefs is usually published, some studies done as advanced degree dissertations, which can contain useful information, may not have been published. An index of North American thesis dissertations since 1860s, Dissertation Abstracts, can be found and searched through DIALOG (see above).

Research Needs

A compilation of the results of an attempted worldwide survey by the ASMFC-ARAC was reported by ASMFC in 1990. The survey queried resource managers on priorities on outstanding major research or information needs to plan, construct, maintain, and manage marine and estuarine man-made reefs for fisheries. Many of the information needs were practical, reflecting a need to be more effective and efficient in developing reefs and documenting benefits. There also was a concern for the role that reefs have on sustainable fishery populations. In brief, artificial reef program managers and fishery managers believe more research and information is required in the following areas, listed in order of priority.

Estuarine Applications

The highest level of interest expressed by reef managers was on the use of artificial reefs in estuaries. The need to know if artificial reefs would support the various life stages of estuarine-dependent fishery resources in the highly variable estuarine environments is of great interest. Also, it is necessary to determine what level of use such reefs can support.

Understanding Reef Community Ecology

The second leading concern is how physical aspects of artificial reef habitat can limit or enhance reef resource abundance and productivity. Managers need to define relationships and possible effective limits or thresholds among reef characteristics, such as area/size, edge habitat, aspect ratio, cubic volume, etc., and fishery function. There also is interest in the ways reefs are used by species, such as temporal abundance patterns and interactions among species on artificial and natural reefs.

Reef Population Life Histories

Reef program managers need to know how artificial reefs support various life stages of reef species, especially juvenile, and the mechanisms involved. Do man-made reefs enhance prey fields and availability, and the growth rates of reef population cohorts? What are the resource migration ranges and pathways? While resources are using artificial reefs, is there a difference in natural and fishing mortalities as compared to other habitats?

Bioengineering and Design

Increasingly, artificial reef managers want to know how artificial reefs can be designed or used to address the needs of specific life stages of reef resources, such as juveniles. This requires an understanding of specific habitat functions and the needs of these life stages.

Harvest Analysis

Artificial reef program managers need data on rates of sustained harvest for various reef resources. Fishery managers need data defining the fishing effort on reefs by various users

to assess the potential to control harvests of associated resources. They are also interested in knowing if artificial reefs can be resource conservation refuges without costly enforcement. The prolonged effects to fish populations of different types of artificial reefs and associated special management zones are also of interest.

Reef Population Dynamics

Reef program managers feel that a definition of the structure and dynamics of reef populations is needed to understand stock/fishery interactions. They also want to know how spacing of reefs, reef materials and condition (height, complexity, overall size, epifaunal state, etc.) affect resource recruitment and stock structure and size. Do artificial reef populations differ from those of the rest of the population in a region and does this difference change with time as artificial reefs mature?

Socio-economics

This aspect of fishery science is often overlooked or under-utilized by reef resource managers. Managers feel, generally, that their socio-economic information need is basic: they want the public benefit of their programs documented. They want to know who uses the reefs and to what extent. They need to know the cost-benefit relationships among reef types, materials, designs, and deployment methods, and how these relate to fishery productivity or other factors, such as user accessibility.

Community Production

Managers want to define any relationships between reef size, configuration and location, and "productivity," in terms of standing stocks, yield to fisheries, and resource growth and survival rates. Does the "Law of Diminishing Returns" apply to reef productivity, especially fishery resources, after a certain reef size or density threshold is reached? There is a need for "real-world" data. Results from a standing stock or production study of a few cubic yards of experimental "reef structure" may not apply to programs that use acres and thousands of tons of reef material, and to fish that require larger habitats. Food webs/chains need to be defined and quantified and trophodynamic models developed to understand how much and what kinds of food must be produced to support sustained reef resource populations. Managers also want quantitative data on productivity of reef fish, invertebrates and plant communities to enable comparisons within and among reefs, and other habitats.

Reef Data Acquisition and Distribution

Artificial reef managers need better databases to develop predictive models of effectiveness of reef designs and deployments. Cost effective, standardized data acquisition methods must be formulated, especially to reduce high labor costs and produce comparable data.

Mitigation

The use of artificial reefs as mitigation for loss of dissimilar habitat has been and will continue to be a controversial topic. Attempting to replace like-for-like habitat is difficult enough, especially functionally. This problem is compounded when reef habitat is used to compensate for losses of other habitat types, even when there are no feasible alternatives. The use of artificial reefs continues to be proposed as habitat loss mitigation, and fishery habitat managers need information on the ability of reefs to replace other habitats.

SUMMARY

In summary, resource managers require more and better fishery science and information to enable artificial reef programs to have maximum sustained beneficial results at lowest costs, and to avoid situations where reefs are found to be detrimental to resources or users. The process to improve dialogue among reef managers, those engaged in or considering reef research, and the agencies capable of, or responsible for providing support for reducing information gaps must continue. Artificial reef programs will continue to expand, partially because of socio-political forces. Scientists, reef managers and funding agencies must work together to focus resources on assuring that the information base for making good public policy decisions on artificial reef use is up-to-date and adequate.